TECHICAL BULLETIN

EHE

TB1009

INDUCTION WELDING OF STAINLESS STEEL TUBING

Stainless Steel was originally the trademarked name for a patented alloy invented in England, which exhibited outstanding corrosion resistance. The original alloy contained 13.5% Chromium & 0.35% Carbon. The term is now used generically to describe a wide range of corrosion & heat resistant alloys containing iron, chromium & nickel. Welded Stainless Steel tubing is widely used, and it can be produced using most welding methods, including high frequency induction, however setup is more critical than with low carbon steels.

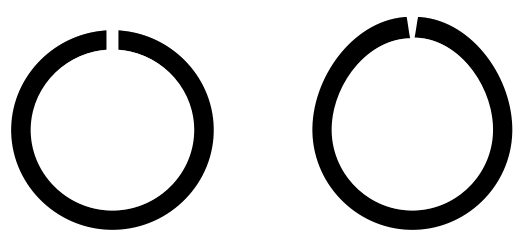
Stainless steel can be successfully welded using high frequency induction welding, however it is less forgiving than carbon steels, and certain potential problems should be addressed if good results are to be attained.

The problems that may be encountered fall into three groups.

- Mechanical
- Electrical
- Thermal
- Chemical

Mechanical considerations.

From a mechanical aspect, stainless steels have much in common with high carbon alloy steels, and they require special roll designs to overcome their resistance to cold forming and to compensate for spring back. If the roll design is incorrect, the inner corner of the strip will meet first, causing sparking, & requiring excessive heat to melt the additional material. There is also a greater chance of oxide inclusions in the weld if the edges do not approach the apex of the weld vee in a parallel presentation.



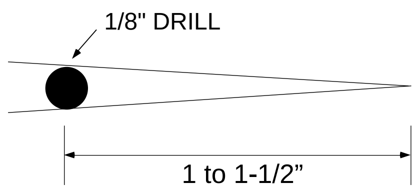
GOOD PRESENTATION BAD PRESENTATION

It is essential to use some type of edge forming in the breakdown passes, and the fin angle is also frequently reduced to improve the edge presentation for stainless. Many mill operators believe that by adjusting the weld rolls to a flat oval, they can compensate for the spring back, but this is of little use because the high frequency skin effect concentrates the heat on the inside corners of the faying edges, overheating them while leaving the outer corners cold. Such tubing will often pass a cone expansion test, but fail a flattening test. It is critical to ensure that the strip edges approach the apex in a parallel presentation, at least from the end of the work coil to the weld point.

Electrical considerations.

Chromium & nickel have the lowest electrical conductivity of all common metals, which is why they are used in the form of NiChrome for heating elements. Although this makes these alloys easy to heat using electrical resistance heating, it requires higher voltages to drive current through the resistance. When induction welding is used to weld these alloys, a higher voltage occurs across the edges of the strip, increasing the likelihood of ionization & consequent flashovers. These flashovers leave pockets of oxidation and pitting on the mating surfaces of the weld, resulting in hidden defects.

The usual solution to this problem is to increase the angle at which the strip edges approach the weld point. An angle of 5° to 8° is common for welding stainless steels. An easy way of measuring this angle is to use a wire of known diameter (a 1/8" twist drill works well) as a feeler gauge between approaching edges. Solving the triangle from the three known sides gives the apex angle. A distance of 1" indicates an approach angle of 8°, 1-1/2" is approximately 5°.



Using a lower frequency for the welder also lowers the voltage across the strip edges. This may provide additional benefits as well, since the current penetration is deeper at lower frequencies, resulting in a greater mass of metal heated to welding temperature. Although this reduces the efficiency, it increases the process stability, resulting in less temperature variation.

Thermal considerations.

Although frequency has some effect on the width of the heat affected zone (HAZ) in induction welding, thermal conduction has a far greater effect, at least at moderate weld speeds. Since stainless steels have very low rates of thermal conduction, little heat is conducted away from the surfaces of the strip edges, where it is produced. This results in a very narrow heat affected zone. This is desirable from a standpoint of efficiency, but because there is such a small mass of material heated to welding temperature, it is very susceptible to temperature variations. The range of temperatures over which stainless steel can be welded is much narrower than for low carbon steels, so a wider HAZ can improve the stability of the welding process.

Three methods can be used to widen the HAZ.

1. Lower welder frequency. (Below 200kHz. is frequently used with good results.)
2. Longer "vee" length (coil further toward entry end)
3. Move impeder back, or use smaller impeder.

Of these three, moving the impeder is by far the most useful since it moves the end of the impeder upstream from the apex, reducing damage from spume. Moving the coil back results in a higher voltage being induced across the edges, and also increases the magnetic flux in the impeder. Lowering the welder frequency is not usually an option except in the case of a few specialized (& expensive!) welders.

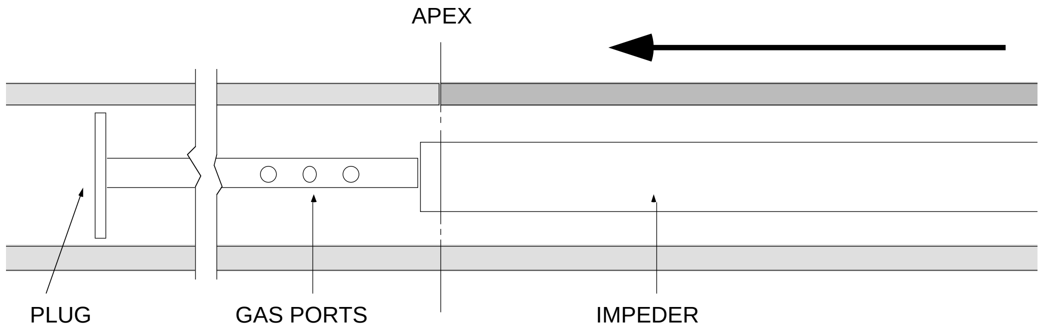
In addition to the thermal conductivity issue, stainless steels have greater hot yield strengths, so the range of temperatures over which a diffusion bond can occur is narrower. The requires that the temperature of the edges be maintained over a narrow range preferably not exceeding 10°C. Apart from contamination problems, any coolant droplets that splash onto the strip edges will cause some chilling & a possible weld defect.

Chemical considerations.

Stainless steels contain between 5% and 20% Chromium, which oxidizes very readily at the temperatures needed for welding. In fact it is this oxide layer that protects the surface of the metal from corrosion, giving it its “stainless” properties. With low carbon steels, the oxides produced melt at a lower temperature than the steel itself, so they are reabsorbed into the hot material & do not generally present a problem.

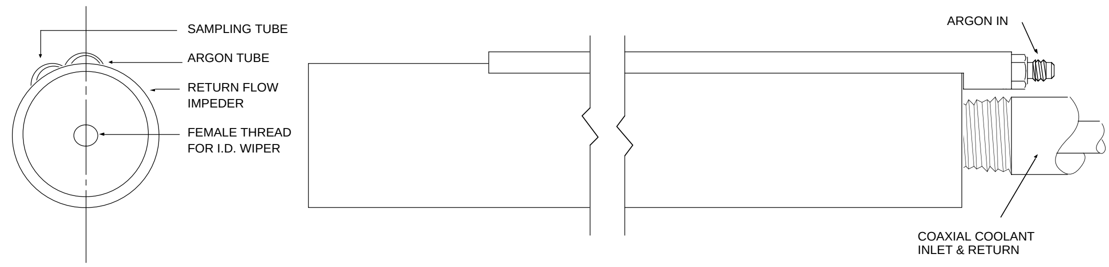
Chromium oxides are hard refractory materials which do not melt at welding temperatures. Oxide inclusions cause weld defects and they must either be forced out of the weld, into the bead, or preferably prevented in the first place. The higher the chromium content, the more difficult it is to weld. Oxidation can be reduced by enclosing the weld area in a low pressure inert shielding gas such as nitrogen.

Simply blowing a jet of inert gas onto the heated part of the tube is not very effective because additional oxygen from the surrounding air is usually mixed in with the gas. Oxygen should be displaced from the inside of the tube as well, since air is carried along with the strip.

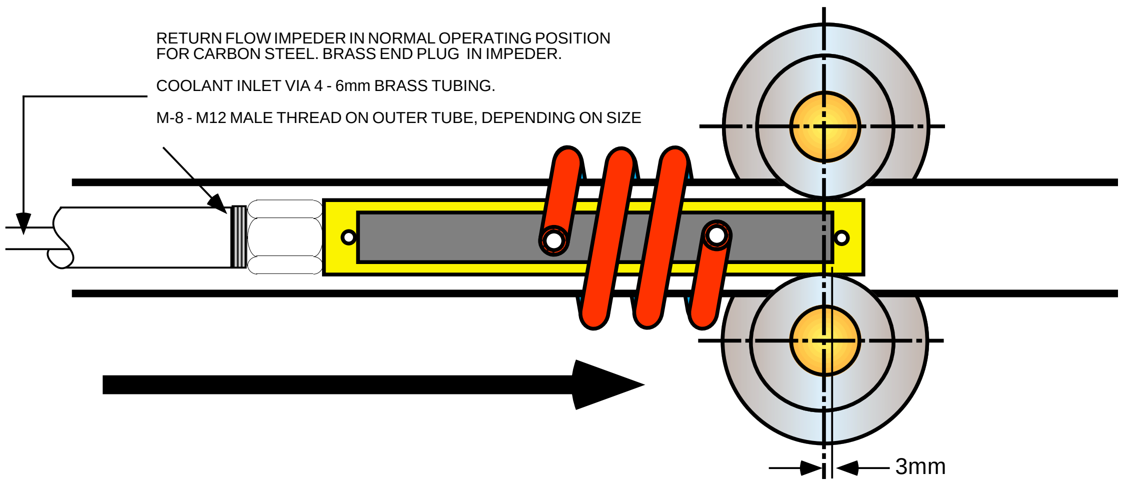


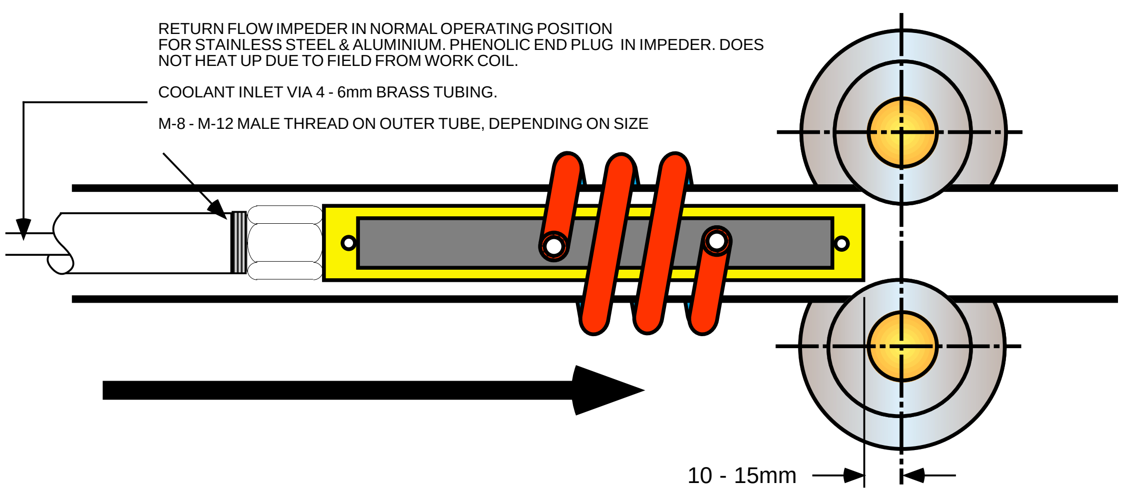
At the temperature used for welding, water disassociates into its components; oxygen & hydrogen. The oxygen does not immediately form O^2 molecules. The monatomic oxygen is highly reactive and will instantly combine with the Chromium to produce oxides. Because of this, it is essential to use return flow impeders when welding all corrosion resistant steels. If return flow impeders are placed with the end of the ferrite upstream from the weld point, in order to widen the HAZ or prevent spume damage, the plugs in the impeder ends should be non-metallic. Metal plugs or fasteners will be induction heated by the coil unless they are past the closure point of the tube.

Hollow return flow impeders can be used with low pressure inert gas purge system, to help displace oxygen from the hot edges of the strip. The diagram above illustrates this. An alternative method is shown on the following page.



RETURN FLOW IMPEDER WITH GAS PURGE & O^2 SAMPLING





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